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AUTEST--PROGRAM TO PERFORM AUTOMATED HYPOTHESIS TESTS FOR NONSTANDARD PROBLEMS

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Educational Testing Service
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AUTEST--Program to Perform Automated Hypothesis Tests for Nonstandard Problems

Abstract

This write-up describes a general computer package that computes asymptotic standard errors and carries out significance tests for a wide variety of problems. A complete description of the theoretical foundations is found in Lord (1973).

AUTEST--Program to Perform Automated Hypothesis Tests for Nonstandard Problems*

Section 1 of this write-up gives the general description of the package. Section 2 describes the algorithm used to compute derivatives numerically. Section 3 describes in detail the required input, the output, and messages which may appear in the output. Section 4 describes the subroutine XIHAT. The package provides the skeleton of this subroutine, and this section gives detailed instructions on how to use it. If the user wishes to change the maximum number of variables or samples or hypotheses, information for this purpose is provided in Section 5. Machine dependent features are listed in Section 6. A complete sample problem is discussed in Section 7, and the input and output are listed.

1. General Description

The package that performs the automated hypothesis testing consists of a main program and eight subroutines. The package is written in FORTRAN IV in double precision and when compiled on an IBM 360/65 using the G compiler, takes 80K. This size will be increased if the user either enlarges the number of variables in a sample (see section 5) or modifies subroutine XIHAT substantially (see section 4).

AUTEST	Main program for automated hypothesis testing. AUTEST reads input, computes derivatives, and calls subroutines COVM, COVS, IN, MATOUT, CHOLES, PROB, and XIHAT.
IN	Subroutine called by AUTEST if input is raw data, to read data and compute means and covariances.

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COVM, COVS	Subroutines called by AUTEST to compute equation (3).
MATOUT	Subroutine called by AUTEST to print upper triangular matrices.
FILL	Subroutine called by MATOUT.
CHOLES	Subroutine called by AUTEST to compute $\hat{C}^{-1}$ by Cholesky's square root method.
PROB	Subroutine called by AUTEST to compute the percentile rank of Q in the appropriate chi square distribution.
XIHAT	Subroutine in which user will supply formulas for $\hat{\xi}$ and any restrictions (see section 4).

2. Computation of Partial Derivatives

The partial derivatives of the elements of $\hat{\xi}$ are computed numerically. All elements in t are held constant except one. This element is increased by some increment, and a value for $\hat{\xi}_a$ (say) is computed; the element is then decreased from its original value by the same increment, and another value of $\hat{\xi}_a$ is computed. The derivative is approximated as the difference between these two values of $\hat{\xi}_a$ divided by twice the increment.

In computations with fixed word length, the optimum size of the increment is not known. An iterative procedure is used in which the size of the increment is decreased up to the point where the difference between two successively computed approximations to the derivative increases (due to truncation error). The first value used for the increment is 0.001. In successive iterations, this is decreased by a factor of 10, up to a maximum of five times. If the differences between successive approximations do not increase, the last derivative computed is used.

The user must scale his data so that 0.001 is a meaningful increment. If he fails to do this, all derivatives, and therefore standard errors, will be zero.

3. Input, Output, Program Messages for User

Input

The user is allowed a maximum of 20 hypotheses, and 2 samples with 10 variables each. With some manipulation of the data, the number of samples can be increased and, correspondingly, the number of variables allowed per sample decreased. This feature will be described later. The following is a description of the input cards required. The user must follow the normal FORTRAN convention of right-adjusting all values within the specified fields.

CARD 1 FORMAT(16I5)

cols. 1-5	NSAMP	The number of independent samples of data. Must be one or two.
cols. 6-10	NH	Number of hypotheses. Must be $1 \leq NH \leq 20$

CARD 2 FORMAT(10A8)

cols. 1-80	TITLE	Title of first sample

CARD 3 FORMAT(16I5)

cols. 1-5	NOBS1	Number of observations in first sample
cols. 6-10	N1	Number of variables in first sample, maximum of 10
cols. 11-15	INPUT	= 0 , input for first sample is raw = 1 , input for first sample are sample means and sample variance-covariance matrix.

CARD 4 FORMAT(10A8)

cols. 1-80 FMT Variable format for reading data for first sample. Will be used for either raw data or means and variance-covariance matrix, depending upon cols. 11-15 of card 3. Must specify a floating-point format.

If INPUT = 0

Card 5+ FORMAT(FMT)

cols. 1-80 RAW(I),(I=1,...,N1) Observations on N1 variables, one record per set of N1 observations, with each set of observations beginning a new record. Punched according to format specified on card 4.

If INPUT = 1

Card 5+ FORMAT(FMT)

cols. 1-80 X(I),(I=1,...,N1) N1 sample means for first set of data, punched according to format specified on card 4.

CARD 6+ FORMAT(FMT)

cols. 1-80 S(I,J),(I=1,...,N1; J=I,...,N1) Upper triangle, including the diagonal, of the sample variance-covariance matrix. This triangular matrix must be punched row by row (each row begins with the diagonal element) with each row beginning

Card 6+ (continued)

a new card according to format specified on card 4. This means that the diagonal elements occupy the first position on the cards.

If cols. 1-5 of card 1 = 2, i.e., there are two samples, then cards 2 through 6+ are repeated for the second sample. The variable names which change, and their meanings are:

NOBS2 - number of observations in the second sample

N2 - number of variables in the second sample, maximum of 10

X2 - means for second sample

S2 - variance-covariance matrix for second sample.

All other variables are reused for the second sample.

It is possible to increase the number of samples up to a maximum of 20, but one must also reduce the number of variables per sample, and specify that the covariances between variables from different samples are zero. The input cards remain essentially the same. In particular, card 1, NSAMP, must still be either one or two.

Suppose we have two samples, each with one variable, i.e., two univariate samples. If NOBS1 = NOBS2 , exactly the same results can be obtained from the program by considering the data as one bivariate sample with $s_{12} = 0$. The input cards for two univariate samples with sample means and covariances as input would be similar to

Card 1 cols. 1-5 NSAMP = 2

Card 2 cols. 1-80 TITLE

Card 3	cols. 1-5	NOBS1
	cols. 6-10	N1 = 1
	cols. 11-15	INPUT = 1
Card 4	cols. 1-80	FMT = (8F10.4) (say)
Card 5	cols. 1-10	X(1)
Card 6	cols. 1-10	S(1,1)
Card 2*	cols. 1-5	TITLE for 2nd sample
Card 3*	cols. 1-5	NOBS2
	cols. 6-10	N2 = 1
	cols. 11-15	INPUT = 1
Card 4*	cols. 1-80	FMT = (8F10.4)
Card 5*	cols. 1-80	X2(1)
Card 6*	cols. 1-10	S2(1,1)

*Indicates second sample.

Considering these data as one bivariate sample we would have

Card 1	cols. 1-5	NSAMP = 1
Card 2	cols. 1-80	TITLE
Card 3	cols. 1-5	NOBS1
	cols. 6-10	N1 = 2
Card 4	cols. 1-80	FMT = (8F10.4)
Card 5	cols. 1-10	X(1)
	cols. 11-20	X(2)
Card 6(a)	cols. 1-10	S(1,1)
	cols. 11-20	S(1,2) = 0
Card 6(b)	cols. 1-10	S(2,2)

Further examples might be of some use here. Suppose the user has four samples of the same size, each with two variables. This can be

handled by the program by considering these data to be one sample (NSAMP = 1) with eight variables and the following sample variance-covariance matrix

$$\begin{matrix} s_{11} & s_{12} & 0 & 0 & 0 & 0 & 0 & 0 \\ & s_{22} & 0 & 0 & 0 & 0 & 0 & 0 \\ & & s_{33} & s_{34} & 0 & 0 & 0 & 0 \\ & & & s_{44} & 0 & 0 & 0 & 0 \\ & & & & s_{55} & s_{56} & 0 & 0 \\ & & & & & s_{66} & 0 & 0 \\ & & & & & & s_{77} & s_{78} \\ & & & & & & & s_{88} \end{matrix}$$

Or we can consider these data as two samples (NSAMP = 2) with 4 variables each and obtain the same result. The sample variance-covariance matrix for the first sample would be

$$\begin{matrix} s_{11} & s_{12} & 0 & 0 \\ & s_{22} & 0 & 0 \\ & & s_{33} & s_{34} \\ & & & s_{44} \end{matrix}$$

and for the second sample

$$\begin{matrix} s^*_{11} & s^*_{12} & 0 & 0 \\ & s^*_{22} & 0 & 0 \\ & & s^*_{33} & s^*_{34} \\ & & & s^*_{44} \end{matrix}$$

* = second sample

By extension of these examples, it is clear that without changing the program, a maximum of 20 univariate samples can be handled if they are all of the same size. In this case, we would treat this as two (NSAMP = 2) samples, each with 10 variables. The sample variance-covariance matrix would be similar for each sample--the main diagonal would contain the variances, and all off-diagonal elements would be zero.

Output

The output from the program is largely self-explanatory. A title is printed at the top of the first page. The number of samples (NSAMP) is also printed, and will be either one or two. It will not reflect the actual number of samples if the user has taken advantage of the facilities described in the input section to expand the number of samples. Also, the time and date of the run and the number of hypotheses being made are printed (see section 6).

For each of two possible samples there is printed the title, number of observations, number of variables, and the variable INPUT. In addition, to provide the user with means of checking his input, the sample means, and upper right triangle of the sample variance-covariance matrix is printed.

The estimated means and variance-covariance matrix are then printed. These values will be identical to the sample values except for those values for which the user has provided formulas for computing different estimates in subroutine XIHAT (see section 4). This output is also provided for user verification of his formulas.

The values of the elements of $\hat{\underset{\sim}{\xi}}$ are printed. In addition, the partial derivatives of each element of $\hat{\underset{\sim}{\xi}}$ with respect to the means and variance-covariance matrices are printed for each sample.

Finally, $\hat{\underset{\sim}{C}}$, the variance-covariance matrix of $\hat{\underset{\sim}{\xi}}$, $\hat{\underset{\sim}{C}}^{-1}$, $Q \equiv \hat{\xi}'\hat{\underset{\sim}{C}}^{-1}\hat{\xi}$, d.f., Q/d.f., and the percentile rank of Q in the appropriate chi square distribution are printed.

Messages

The program detects three conditions that will result in the printing of a message:

1. If NSAMP is greater than two, the actual value of NSAMP that the user supplied is printed and the program exists.

2. The program uses the value of the last derivative computed as the partial derivative, and continues on to the computation of the next partial derivative. If a derivative is obtained from computation with the smallest increment, a message is printed.

3. If, during the inversion of $\hat{\underset{\sim}{C}}$, a pivotal element becomes less than $0.5X10^{-12}$, the matrix is considered singular. The inversion halts, and the program exits.

4. Subroutine XIHAT

Subroutine XIHAT is the subroutine in which the user inserts coding for his specific null hypotheses $\hat{\underset{\sim}{\xi}} = 0$. If the user wishes to specify estimates other than sample means and variance-covariances, he also inserts the coding in this subroutine.

Variables containing information transmitted to this subroutine as arguments are as follows (these names differ slightly from the corresponding variable names in AUTEST):

Variable name	Dimension	Contents
X	10	Sample means for first sample
S	10 by 10	Sample variance-covariance matrix for first sample
X2	10	Sample means for second sample
S2	10 by 10	Sample variance-covariance matrix for second sample
N		Number of variables in first sample
N2		Number of variables in second sample
NOBS		Number of observations for first sample
NOBS2		Number of observations for second sample
NSAMP		Either 1 or 2, same variable as card 1 of input

Variables containing information transmitted from this subroutine as arguments are as follows:

M	10	Estimated means for first sample
$	10 by 10	Estimated variance-covariance matrix for first sample
M2	10	Estimated means for second sample
$2	10 by 10	Estimated variance-covariance matrix for second sample
XIHAT	20	The values of $\hat{\underset{\sim}{\xi}}$ computed in this subroutine

The FORTRAN statements down to 9999 transfer the sample means and covariances into the estimated means and covariances. This insures that the estimated means and covariances will be the same as the sample values unless modified by the user.

If the user wishes to specify other estimates for some or all of the means and covariances, he must insert the FORTRAN code to do that operation between the first two asterisk cards. He must follow the following rules:

1. In referring to any element of any covariance matrix, the second subscript must be greater than or equal to the first, i.e., only the upper right triangle is to be worked with.
2. The estimates supplied must appear to the left of an equal sign.
3. The first line of FORTRAN code must <u>not</u> be a format statement, and must have the statement number 100.
4. Statement numbers 9998 and 9999 must not be used.

The user <u>must</u> insert the FORTRAN code for the computation of the elements of $\hat{\underline{\xi}}$ between the second set of asterisk cards. This code may consist of a number of statements. The user may refer to any variable previously defined. The following rules must be followed:

1. In referring to any element of any variance-covariance matrix, the second subscript must be greater than the first.
2. Statement numbers 9998 and 9999 must not be used, and statement numbers used in specifying estimates (if any) must not be repeated.

3. If no estimates were specified, the first line of code must not be a format statement, and must have the statement number 100.

4. The variables XIHAT(I) for I = 1,NH must appear to the left of an equal sign.

5. Instructions for Program Changes

Increasing the Number of Variables and/or Hypotheses

The following vectors in the main program AUTEST have dimensions which are dependent upon the number of variables in each sample and/or the number of hypotheses. Let n_1 indicate the maximum number of variables in the first sample, n_2 be the maximum number in the second sample, and n_h be the number of elements in $\hat{\underset{\sim}{\xi}}$.

$MSAVE(n_1)$, $\$SAVE(n_1,n_2)$, $M(n_1)$, $\$(n_1,n_1)$, $S(n_1,n_1)$, $X(n_1)$,

$M2SAVE(n_2)$, $\$2SAVE(n_2,n_2)$, $M2(n_2)$, $\$2(n_2,n_2)$, $S2(n_2,n_2)$, $X2(n_2)$

$DER(\max[\frac{n_1(n_1+1)}{2}+n_1, \frac{n_2(n_2+1)}{2}+n_2], n_h)$

$TAU(n_1+n_2+n_1^2+n_2^2)$

$DOUT(\max(n_1,n_2), \max(n_1,n_2))$

$INDEX(\max(n_1,n_2))$

$C(n_h,n_h)$, $XIH(n_h)$, $XI1(n_h)$, $XI2(n_h)$, $RXIHAT(n_h)$,

$DOUTX(n_h,n_h)$, $CINV(n_h,n_h)$, $WORK(n_h)$

The equivalencing of TAU to MSAVE, M2SAVE, $SAVE, and $2SAVE is arranged so that MSAVE(1) is TAU(1), M2SAVE(1) is TAU(n_1 + 1), $SAVE(1,1) is TAU($n_1 + n_2 + 1$) and $2SAVE(1,1) is TAU($n_1 + n_2 + n_1^2 + 1$).

The user may change the maximum number of variables and/or hypotheses by using the above formulas for determining the correct dimension and equivalence statements. There are only three restrictions: (1) the maximum number of variables must be the same for both samples; (2) the variable IDEM must be set equal to the maximum number of variables and IA must be set to the maximum number of hypotheses; (3) all subroutine dimension statements must be changed to reflect the new dimensions in AUTEST.

Changing Derivative Computation

The algorithm to compute the partial derivatives required is described in section 2. If the user wishes to change the initial value of the increment, he supplies a different value for the variable DEL. If the user wishes to change the number of iterations, he changes the code to test the variable IDEL (iteration counter) against the maximum number of iterations desired.

6. Machine Dependent Features

There are a number of features used in this program which are peculiar to FORTRAN on an IBM 360 in addition to the 4 byte word, hexadecimal machine. Almost all variables that are normally floating-point are implicitly defined as double-precision floating point numbers. Two machine subroutines are called: (1) SETCLK to set the interval timer for this program, (2) DATET to get date and time of day for printing on output.

Either or both of these features may be eliminated by the user (making appropriate modifications of statement numbers, etc.) or replaced.

7. Sample Problem

For this example we have one sample with four variables. The number of cases in the sample is 649, and we have already computed the sample means and variance/covariance matrix, which we will use as input to AUTEST.

We wish to test only one hypothesis:

$$H_0: \quad \rho_{13}/\sqrt{\rho_{11}\rho_{33}} = 1 \quad . \tag{1}$$

We impose the following restrictions:

$$\left.\begin{aligned} \hat{\sigma}_1^2 = \hat{\sigma}_2^2 &= \tfrac{1}{2}\,(s_1^2 + s_2^2) \\ \hat{\sigma}_3^2 = \hat{\sigma}_4^2 &= \tfrac{1}{2}\,(s_3^2 + s_4^2) \\ \hat{\sigma}_{13} = \hat{\sigma}_{14} = \hat{\sigma}_{23} = \hat{\sigma}_{24} &= \tfrac{1}{4}\,(s_{13} + s_{14} + s_{23} + s_{24}) \end{aligned}\right\} \quad , \tag{2}$$

where the $\hat{}$ denotes estimators, and the s_{ij} are sample values.

The hypothesis (1) can be expressed, under the restrictions (2) as

$$\hat{\xi} = \hat{\sigma}_{13}^2 - \hat{\sigma}_{12}\hat{\sigma}_{34} \quad . \tag{3}$$

For this problem, our input would be the following set of cards:

```
    1    1
TEST DATA 19      HO:  RHO13/SQRT(RHO11*RHO33) = 1
  649     4     1
(4F7.4)
 000000 000000 000000 000000*
 863979 577751 568651 588986
 862632 593117 596683
 972850 738201
 978193
```

*Note: Since the sample means do not enter into the hypothesis, we can input zeros for them.

We must insert in the skeleton of subroutine XIHAT the Fortran coding for the restrictions and the hypothesis. Following the instructions given in Section 4, we insert the following code between the first set of asterisk cards to specify the restrictions (2), starting with statement number 100.

```
100  $(1,1) = .5D0*(S(1,1)+S(2,2))
     $(2,2) = $(1,1)
     $(3,3) = .5D0*(S(3,3)+S(4,4))
     $(4,4) = $(3,3)
     $(1,3) = .25D0*(S(1,3)+S(1,4)+S(2,3)+S(2,4))
     $(1,4) = $(1,3)
     $(2,3) = $(1,3)
     $(2,4) = $(1,3)
```

The matrix $ will contain the estimated variance/covariance matrix. The matrix S contains the sample values that were read in on cards 6 thru

9. In addition, since we work with only the upper triangle of either matrix, the second subscript is greater than or equal to the first.

Between the second set of asterisk cards we insert the coding for the hypothesis (3):

```
XIHAT(1) = $(1,3)*$(1,3)-$(1,2)*$(3,4)     .
```

Subroutine XIHAT and the output from this example are reproduced on the following pages.

```
C
C
C      AUTOMATED LARGE SAMPLE HYPOTHESIS TESTING:  TO TEST VECTOR HYPOTHESES
C     ABOUT MEANS AND COVARIANCES FROM ONE OR TWO LARGE SAMPLES.
C
C     PROGRAM COMPUTES THE TEST STATISTICS XIHAT(I), I=1,2,...,NH, WHERE
C     NH IS THE NUMBER OF HYPOTHESES, VARIANCE/COVARIANCE MATRIX FOR THE
C     XIHAT, Q, AND PRECENTILE RANK OF Q IN APPROPRIATE CHI-SQUARE DISTRIBUTION.
C
C     SUBROUTINE XIHAT IS WRITTEN FOR USER MODIFICATION:
C          (1) USER MAY SUPPLY CODING TO COMPUTE RESTRICTED MEANS AND
C          COVARIANCES FROM SAMPLE MEANS AND COVARIANCES.  IF CODING
C          IS NOT SUPPLIED, NO RESTRICTIONS WILL BE ASSUMED.
C          (2) USER MUST SUPPLY CODING TO COMPUTE THE XIHAT  FROM RESTRICTED
C          AND/OR UNRESTRICTED MEANS AND COVARIANCES.
C
C     MAXIMUM OF TWO SAMPLES, MAXIMUM OF TEN VARIABLES PER SAMPLE
C     MAXIMUM OF TWENTY HYPOTHESES
C
C     USER MAY INPUT RAW DATA  OR SAMPLE MEANS AND COVARIANCES.
C
C     MARTHA STOCKING,  OCTOBER, 1972.
C
C
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 MSAVE(10),M2SAVE(10), $SAVE(10,10),$2SAVE(10,10)
      REAL*8 M(10),M2(10),$(10,10),$2(10,10)
      REAL*4 DATET(5)
      DIMENSION DER(65,20),C(20,20),XIH(20),XI1(20),XI2(20),RXIHAT(20)
      DIMENSION DOUTX(20,20),HXI(12),CINV(20,20),WORK(20)
      DIMENSION HXI1(12)
      DIMENSION S(10,10),S2(10,10),X(10),X2(10),TITLE(10),FMT(10
     1),D(4),DELD(3),        INDEX(10),TAU(220)
      EQUIVALENCE (TITLE(1),FMT(1)),(TAU(1),MSAVE(1)),(TAU(11),M2SAVE(1)
     1),(TAU(21),$SAVE(1,1)),(TAU(121),$2SAVE(1,1))
      DIMENSION HNAME(12),FMTS(5)
      DIMENSION DOUT(10,10),HNDER(12),HNAM2(12)
      DATA HNAME/'SAMPLE V','ARIANCE/','COVARIAN','CE MATRI','X       ',
     17*'        '/
      DATA HNAM2/'ESTIMATE','D VARIAN','CE/COVAR','IANCE MA','TRIX    ',
     17*'        '/
      DATA HNDER/'VARIANCE','/COVARIA','NCE MATR','IX      ',8*'
     1'/
      DATA FMTS   /',13X  ',',F13.0',',F13.5',2*'      '/
      DATA HXI/'VARIANCE','/COVARIA','NCE MATR','IX OF XI','HATS    ',
     17*'        '/
      DATA HXI1/'INVERSE ','OF VAR/C','OV MATRI','X OF XIH','ATS     ',
     17*'        '/
      CALL SETCLK
      IDEM=10
      IA=20
 9000 READ(5,1001,END=9999) NSAMP,NH
 1001 FORMAT(16I5)
      IF(NSAMP.LE.2) GO TO 10
      WRITE(6,1005) NSAMP
 1005 FORMAT(1H1,'********** MAXIMUM OF TWO SAMPLES ALLOWED.  USER SPECI
     1FIED',I10,3X,'PROGRAM WILL TERMINATE')
      GO TO 9999
   10 IF(NH.LE.IA) GO TO 15
      WRITE(6,1006) NH
 1006 FORMAT(1H1,'********** MAXIMUM OF 20 HYPOTHESES ALLOWED.  USER SPE
     1CIFIED',I10,3X,'PROGRAM WILL TERMINATE')
      GO TO 9999
```

```
   15 CALL DATE(DATET)
      WRITE(6,1010) NSAMP,DATET,NH
 1010 FORMAT(1H1,20X,'PROGRAM TO TEST HYPOTHESES ABOUT MEANS AND COVARIA
     1NCES FOR LARGE SAMPLES.',/1HO,30X,'NUMBER OF SAMPLES =',I5,20X, 5A
     14,/1HO,30X,'NUMBER OF HYPOTHESES =',I5)
      READ(5,1015) TITLE
 1015 FORMAT(10A8)
      WRITE(6,1020) TITLE
 1020 FORMAT(1HO,10X,'TITLE OF DATA FOR SAMPLE 1:',3X,10A8)
      READ(5,1001) NOBS1,N1,INPUT
      WRITE(6,1025) NOBS1,N1,INPUT
 1025 FORMAT(1HO,20X,'NUMBER OF OBSERVATIONS =',I10,
     1/21X,'NUMBER OF VARIABLES =',I5,
     2/21X,'INPUT =',I5)
      IF(INPUT.EQ.1) GO TO 20
C
C     INPUT FOR FIRST SAMPLE IS RAW DATA
C
      READ(5,1015) FMT
      CALL IN(NOBS1,N1,X,S,FMT)
      GO TO 40
C
C     INPUT FOR FIRST SAMPLE IS MEANS AND COVARIANCES
C
   20 READ(5,1015) FMT
      READ(5,FMT) (X(I),I=1,N1)
      DO 30 I=1,N1
   30 READ(5,FMT) (S(I,J),J=I,N1)
   40 DO 50 I=1,N1
   50 INDEX(I)=I
      WRITE (6,1027) FMT
 1027  FORMAT(21X,'USER SUPPLIED FORMAT FOR SAMPLE 1 : ',5A8,/,58X,5A8,/,
     111X,'**********NOTE: FOR VAR/COV MATRIX - DIAGONAL ELEMENT MUST BE
     5GIN EACH RECORD')
      WRITE(6,1030) (INDEX(I),I=1,N1)
 1030 FORMAT(1HO,5X,'SAMPLE MEANS'/(10I13))
      WRITE(6,1035) (X(I),I=1,N1)
 1035 FORMAT(10E13.5)
      CALL MATOUT(IDEM  ,1,N1,1,N1,S,FMTS,HNAME,8,0,2,0,0,1,0)
      IF(NSAMP.EQ.1) GO TO 120
      READ(5,1015) TITLE
      WRITE(6,1037) TITLE
 1037  FORMAT(1HO,10X,'TITLE OF DATA FOR SAMPLE 2:',3X,10A8)
      READ(5,1001) NOBS2,N2,INPUT
      WRITE(6,1025) NOBS2,N2,INPUT
      IF(INPUT.EQ.1) GO TO 70
C
C     INPUT FOR SECOND SAMPLE IS RAW DATA
      READ(5,1015) FMT
      CALL IN(NOBS2,N2,X2,S2,FMT)
      GO TO 85
C
C     INPUT FOR SECOND SAMPLE IS MEANS AND COVARIANCES
C
   70 READ(5,1015) FMT
      READ(5,FMT) (X2(I),I=1,N2)
      DO 80 I=1,N2
   80 READ(5,FMT) (S2(I,J),J=I,N2)
   85 DO 90 I=1,N2
   90 INDEX(I)=I
      WRITE (6,100) FMT
  100  FORMAT(21X,'USER SUPPLIED FORMAT FOR SAMPLE 2 : ',5A8,/,58X,5A8,/,
     111X,'**********NOTE: FOR VAR/COV MATRIX - DIAGONAL ELEMENT MUST BE
     5GIN EACH RECORD')
      WRITE(6,1030) (INDEX(I),I=1,N2)
      WRITE(6,1035) (X2(I),I=1,N2)
```

```
      CALL MATOUT(IDEM  ,1,N2,1,N2,S2,FMTS,HNAME,8,0,2,0,0,1,0)
C
C     OBTAIN  ESTIMATED MEANS AND COVARIANCES AND INITIAL VALUE OF XIHAT
C
  120 CALL XIHAT(X,S,X2,S2,MSAVE,$SAVE,M2SAVE,$2SAVE,N1,N2,NOBS1,NOBS2,
     1NSAMP,XIH)
      WRITE(6,1055)
 1055 FORMAT(1HO,10X,' ESTIMATED MEANS AND VAR/COV FOR FIRST SAMPLE')
      DO 130 I=1,N1
  130 INDEX(I)=I
      WRITE(6,1040) (INDEX(I),I=1,N1)
 1040 FORMAT(1HO,5X,'ESTIMATED MEANS'/(10I13))
      WRITE(6,1035) (MSAVE(I),I=1,N1)
      CALL MATOUT(IDEM  ,1,N1,1,N1,$SAVE,FMTS,HNAM2,8,0,2,0,0,1,0)
      IF(NSAMP.EQ.1) GO TO 170
      WRITE(6,1060)
 1060 FORMAT(1HO,10X,' ESTIMATED MEANS AND VAR/COV FOR SECOND SAMPLE')
      DO 150 I=1,N2
  150 INDEX(I)=I
      WRITE(6,1040) (INDEX(I),I=1,N2)
      WRITE(6,1035) (M2SAVE(I),I=1,N2)
      CALL MATOUT(IDEM  ,1,N2,1,N2,$2SAVE,FMTS,HNAM2,8,0,2,0,0,1,0)
C
C      MAIN COMPUTATION LOOP TO COMPUTE DERIVATIVES FOR VECTOR HYPOTHESES
C      AND FORM PARTIAL SUMS FOR VAR/COV MATRIX OF HYPOTHESES
C
C
  170 WRITE(6,1050) (I,XIH(I),I=1,NH)
 1050 FORMAT(1HO,10X,'NUMERICAL VALUES OF NULL HYPOTHESES'/(1H ,5(5X,'('
     1,I2,')',E16.8)))
      DO 173 I=1,NH
      DO 173 J=I,NH
      C(I,J)=0.0
  173 CONTINUE
      ISTX=0
      ISTS=IDEM
      IEND=N1
      INC=IDEM+1
      MULT=IDEM
  175 DO 900 IH=1,NH
      L=0
      DO 900 MEAN=1,2
      GO TO (180,190),MEAN
  180 ISTART=ISTX
      GO TO 200
  190 ISTART=ISTS
      ICT=IEND+1
  200 DO 305 I=1,IEND
      GO TO (210,220),MEAN
  210 ICT=1
      ISTART=ISTART+1
      GO TO 230
  220 ICT=ICT-1
      ISTART=ISTART+INC
  230 DO 300 J=1,ICT
      L=L+1
      IPOS=ISTART+(J-1)*MULT
      IDEL=1
      DEL=.001D0
      SAVE=TAU(IPOS)
      IST=1
  235 DO 250 JJ=IST,4
      TAU(IPOS)=SAVE+DEL
      CALL XIHAT(MSAVE,$SAVE,M2SAVE,$2SAVE,M,$,M2,$2,N1,N2,NOBS1,NOBS2,
     1NSAMP,XI1)
      TAU(IPOS)=SAVE-DEL
```

```
      CALL XIHAT(MSAVE,SSAVE,M2SAVE,S2SAVE,M,S,M2,S2,N1,N2,NOBS1,NOBS2,
     1NSAMP,XI2)
      D(JJ)=(XI1(IH)-XI2(IH))/(2.D0*DEL)
      IF(JJ.EQ.1) GO TO 237
      DELD(JJ-1)=DABS(D(JJ)-D(JJ-1))
  237 IF(JJ.NE.3) GO TO 240
      IF(DELD(2).LT.DELD(1)) GO TO 240
      DER(L,IH)=D(1)
      GO TO 290
  240 DEL=DEL*.1D0
      IDEL=IDEL+1
  250 CONTINUE
      IF(DELD(3).LT.DELD(2)) GO TO 260
      DER(L,IH)=D(2)
      IF(DELD(3).LT.DELD(1)) DER(L,IH)=D(3)
      GO TO 290
  260 DELD(1)=DELD(2)
      DELD(2)=DELD(3)
      DO 270 II=1,3
  270 D(II) =D(II+1)
      IST=4
      IF(IDEL.GT.6) GO TO 280
      GO TO 235
  280 WRITE(6,1066) DEL,IH
 1066 FORMAT(1HO,'DELTA =',E20.8,3X,'TOO SMALL, DERIVATIVE SET TO LAST O
     1NE COMPUTED',3X,'FOR XIHAT(',I2,')')
      IF(ISTX.NE.0) GO TO 1085
      WRITE(6,1071) IPOS,SAVE,D(4)
 1071 FORMAT(1HO,'  FIRST SAMPLE, POSITION OF VARIABLE IN TAU VECTOR =',I3,3X
     1I3,/17X,'VALUE =',E20.8,/17X,'DERIVATIVE =',E20.8)
      GO TO 1100
 1085 WRITE(6,1072) IPOS,SAVE,D(4)
 1072 FORMAT(1HO,'  SECOND SAMPLE, POSITION OF VARIABLE IN TAU VECTOR ='
     1,I3,/18X,'VALUE =',E20.8,/18X,'DERIVATIVE =',E20.8)
 1100 DER(L,IH)=D(4)
  290 TAU(IPOS)=SAVE
  300 CONTINUE
  305 CONTINUE
      IF(ISTX.NE.0) GO TO 330
      GO TO (310,320),MEAN
  310 WRITE(6,1210) IH
 1210 FORMAT(1HO,//,' DERIVATIVES OF XIHAT(',I2,') FOR FIRST SAMPLE')
      WRITE(6,1220) (DER(LL,IH),LL=1,L)
 1220 FORMAT(1HO,'MEANS',/(5E20.8))
      GO TO 900
  320 LL=N1
      DO 323 I=1,N1
      DO 323 J=I,N1
      LL=LL+1
      DOUT(I,J)=DER(LL,IH)
  323 CONTINUE
      CALL MATOUT(IDEM,1,N1,1,N1,DOUT,FMTS,HNDER,8,0,2,0,0,1,0)
      GO TO 900
  330 GO TO (340,350),MEAN
  340 WRITE(6,1230) IH
 1230 FORMAT(1HO,//,' DERIVATIVES OF XIHAT(',I2,') FOR SECOND SAMPLE')
      WRITE(6,1220) (DER(LL,IH),LL=1,L)
      GO TO 900
  350 LL=N2
      DO 353 I=1,N2
      DO 353 J=I,N2
      LL=LL+1
      DOUT(I,J)=DER(LL,IH)
  353 CONTINUE
      CALL MATOUT(IDEM,1,N2,1,N2,DOUT,FMTS,HNDER,8,0,2,0,0,1,0)
  900 CONTINUE
```

```
      CALL XIHAT(X,S,X2,S2,M,$,M2,$2,N1,N2,NOBS1,NOBS2,NSAMP,RXIHAT)
      IF(ISTX.NE.0) GO TO 920
      CALL COVM(DER,$,NOBS1,N1,C,NH)
      CALL COVS(DER,$,NOBS1,N1,C,NH)
      IF(NSAMP.EQ.1) GO TO 910
      IEND=N2
      ISTX=IDEM
      ISTS=IDEM*INC
      GO TO 175
  920 CALL COVM(DER,$2,NOBS2,N2,C,NH)
      CALL COVS(DER,$2,NOBS2,N2,C,NH)
  910 CALL MATOUT(IA,1,NH,1,NH,C,FMTS,HXI,8,0,1,0,0,1,0)
      CALL CHOLES(IA,NH,C,CINV,WORK,D,3,.5D-12,IERR)
      CALL MATOUT(IA,1,NH,1,NH,CINV,FMTS,HXI1,8,0,1,0,0,1,0)
      IF(IERR.EQ.1) GO TO 9000
      CHISQR=0.D0
      DO 950 J=1,NH
      DO 950 I=1,NH
      CHISQR=CHISQR+CINV(I,J)*XIH(I)*XIH(J)
  950 CONTINUE
      DF=NH
      CDF=CHISQR/DF
      CALL PROB(CDF,DF,P)
      WRITE(6,955) CHISQR,DF,CDF,P
  955 FORMAT(1HO,'CHI-SQUARE =',E16.8,3X,'D.F. =',F5.0,3X,'CHISQR/DF =',
     1E16.8,3X,'PROBABILITY =',F10.6)
      GO TO 9000
 9999 CALL EXIT
      END
      SUBROUTINE CHOLES(IA,N,A,B,Y,D,IND,EPS,IERR)
C     FOR A GIVEN SYMMETRIC, POSITIVE DEFINITE MATRIX A OF ORDER N
C     THIS SUBROUTINE COMPUTES B=INVERSE OF A. ONLY THE LOWER HALF
C     OF A IS USED. THE METHOD OF INVERSION IS CHOLESKYS SQUARE ROOT
C     METHOD AS DESCRIBED BY DICKMAN AND KAISER, EDUC. PSYCH. MEASMT.,
C     21,1961,721-727. IF ANY PIVOTAL ELEMENT IS LESS THAN EPS, THE
C     MATRIX A IS CONSIDERED SINGULAR AND CONTROL IS TRANSFERRED TO THE
C     CALLING PROGRAM WITH IERR=1. OTHERWISE IERR IS ZERO.
C     IF IND=1, THE DETERMINANT OF A IS STORED IN D AND THE NEGATIVE
C     OF THE INVERSE IS STORED IN THE LOWER HALF OF B.
C     IF IND=2, THE INVERSE IS STORED IN THE LOWER HALF OF B.
C     IF IND=3, THE FULL INVERSE IS STORED IN B.
C     IF THE MATRIX A CAN BE DESTROYED, A AND B CAN BE THE SAME MATRIX.
      IMPLICIT REAL*8(A-H,P-Z),LOGICAL*1(O)
      DIMENSION A(IA,IA),B(IA,IA),Y(IA)
      IERR=0
      DO 5 I=1,N
      DO 5 J=1,I
    5 B(I,J)=A(I,J)
      IF(N.EQ.1) GO TO 100
      D=1.
      DO 40 L=1,N
      F=B(I,1)
      IF(F.LT.EPS) GO TO 120
      D=D*F
      F=1./F
      DO 20 I=1,N
   20 Y(I)=B(I,1)
      DO 30 I=2,N
      H=Y(I)*F
      DO 30 J=2,I
   30 B(I-1,J-1)=B(I,J)-Y(J)*H
      DO 35 J=2,N
   35 B(N,J-1)=-Y(J)*F
   40 B(N,N)=-F
      IF(IND-1) 110,110,50
   50 DO 60 I=1,N
```

```
      DO 60 J=1,I
   60 B(I,J)=-B(I,J)
      IF(IND-2) 110,110,55
   55 DO 70 I=2,N
      I1=I-1
      DO 70 J=1,I1
   70 B(J,I)=B(I,J)
  110 RETURN
  120 WRITE(6,1) L,B(1,1),D
      IERR=1
      RETURN
    1 FORMAT (37HOTHE MATRIX IS NOT POSITIVE DEFINITE ,I4,2F14.8)
  100 B(1,1)=1.D0/ B(1,1)
      RETURN
      END
      SUBROUTINE IN(NSAMP,LITTLN,X,S,FMT)
C
C     SUBROUTINE TO INPUT RAW DATA AND COMPUTE SAMPLE MEANS AND COVARIAN
C     CE) FOR AUTEST
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION FMT(10),S(10,10),RAW(10),X(10)
      DO 5 I=1,LITTLN
      X(I)=0.D0
      DO 5 J=I,LITTLN
      S(I,J)=0.D0
    5 CONTINUE
      DO 15 K=1,NSAMP
      READ(5,FMT) (RAW(IN),IN=1,LITTLN)
      DO 15 I=1,LITTLN
      X(I)=X(I)+RAW(I)
      DO 15 J=I,LITTLN
      S(I,J)=S(I,J)+RAW(I)*RAW(J)
   15 CONTINUE
      FN=NSAMP
      RECN=1.D0/FN
      RECN2=1.D0/(FN*FN)
      DO 20 I=1,LITTLN
      DO 20 J=I,LITTLN
      S(I,J)=RECN2*(FN*S(I,J)-X(I)*X(J))
   20 CONTINUE
      DO 30 I=1,LITTLN
   30 X(I)=X(I)*RECN
      RETURN
      END
      SUBROUTINE COVM(DER,S,NOBS,N,C,NH)
C
C     SUBROUTINE TO COMPUTE PARTIAL SUMS FOR VARXI OF FORM D(I)*D(J)*COV
C     (TI,TJ) FOR TI AND TJ ARE MEANS
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION DER(65,20),S(10,10),C(20,20)
      RECN=1.D0/DFLOAT(NOBS)
      DO 200 IA=1,NH
      DO 200 IB=IA,NH
      VARCOV=0.D0
      DO 100 I=1,N
      T=DER(I,IA)
      T1=DER(I,IB)
      DO 50 J=I,N
      TEMP=T*DER(J,IB)*S(I,J)*RECN
      IF(I.NE.J) TEMP=TEMP+T1*DER(J,IA)*S(I,J)*RECN
      VARCOV=VARCOV+TEMP
   50 CONTINUE
  100 CONTINUE
      C(IA,IB)=C(IA,IB)+VARCOV
```

```
      C(IB,IA)=C(IA,IB)
  200 CONTINUE
      RETURN
      END
      SUBROUTINE COVS(DER,S,NOBS,N,C,NH)
C
C     SUBROUTINE TO COMPUTE PARTIAL SUMS FOR VARXI OF FORM D(I)*D(J)*COV
C     (TI,TJ) WHERE TI AND TJ ARE VAR/COV.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION DER(65,20),S(10,10),C(20,20)
      RECN=1.D0/DFLOAT(NOBS)
      IST=N+1
      NSTAR=(N*(N+1))/2+N
      DO 200 IA=1,NH
      DO 200 IB=IA,NH
      VARCOV=0.D0
      IG=1
      IH=1
      DO 100 IROW=IST,NSTAR
      I=IG
      J=IH
      DO 70 ICOL=IROW,NSTAR
      T1=S(IG,I)
      IF(IG.GT.I) T1=S(I,IG)
      T2=S(IH,J)
      IF(IH.GT.J) T2=S(J,IH)
      T3=S(IG,J)
      IF(IG.GT.J) T3=S(J,IG)
      T4=S(IH,I)
      IF(IH.GT.I) T4=S(I,IH)
      TEMP=DER(IROW,IA)*DER(ICOL,IB)*RECN*(T1*T2+T3*T4)
      IF(ICOL.NE.IROW) TEMP=TEMP+DER(ICOL,IA)*DER(IROW,IB)*RECN*(T1*T2+T
     13*T4)
      VARCOV=VARCOV+TEMP
      J=J+1
      IF(J.LE.N) GO TO 70
      I=I+1
      J=I
   70 CONTINUE
      IH=IH+1
      IF(IH.LE.N) GO TO 100
      IG=IG+1
      IH=IG
  100 CONTINUE
      C(IA,IB)=C(IA,IB)+VARCOV
      C(IB,IA)=C(IA,IB)
  200 CONTINUE
      RETURN
      END
      SUBROUTINE PROB (X,DF,R)
C                        METIOA
      REAL*8 XXD
C     CHI-SQUARED INTEGRAL (S15), ALGORITHM 299, I. D. HILL AND
C     M. C. PIKE,  COMM. OF ACM, VOL. 10, NO. 4
C     COMPUTES THE PROBABILITY THAT CHI-SQUARE ON DF DEGREES OF
C     FREEDOM EXCEEDS X
      NF=DF
      XD=X*DF
      XXD=XD/2.
      IF(XD.LT.0. .OR. DF.LT. 1.) GO TO 5
      IF(XD.EQ.0.) GO TO 7
      A=XD*.5
      JA=A
      IX=NF/2
      Z=1.-(DF*.5-FLOAT(IX))
```

```
      MEV=Z
      IF(MEV.EQ.1 .OR. (NF.GT.2 .AND.JA.LT.88)) Y=EXP(-A)
      S=Y
      IF(MEV.EQ.0) S=DERF(-DSQRT(XXD))+1.
      IF(NF.LE.2) GO TO 4
      IX=(NF-1)/2
      IF(JA.GT.88) GO TO 2
      E=1.0
      IF(MEV.NE.1) E=.564189584/SQRT(A)
      C=0.
      DO 1 J=1,IX
      E=E*A/Z
      Z=Z+1.
1     C=C+E
      R=C*Y+S
      GO TO 6
2     E=0.
      IF(MEV.NE.1) E=.572364943
      C=ALOG(A)
      DO 3 J=1,IX
      E=ALOG(Z)+E
      S=EXP(C*Z-A-E)+S
3     Z=Z+1.
4     R=S
      GO TO 6
5     R=0.0
6     RETURN
7     R=1.0
      RETURN
      END
      SUBROUTINE MATOUT(NRD,IR,NR,IC,NC,A,FMT,HNAME,NCP,MDEC,ISOUT,      MATOUT 1
     1IMASTD,MASTD,INMVR,VARNAM)                                         MATOUT 2
      DIMENSION D1(60)
      REAL*8 A(1)
      REAL*8         FMT(12),FMAT(62),HNAME(12),VARNAM(1),D(2)          MATOUT 4
      DATA FMAT/62*'          '/                                        MATOUT 5
      CALL FILL(D(1),8H,    I4   )                                      MATOUT 6
      CALL FILL(D(2),8H,A8,I4   )                                       MATOUT 8
      B1=10.**MDEC                                                      MATOUT 9
      NPG=0                                                             MATOUT10
      NCPR=IC-1                                                         MATOUT11
      MIT=1                                                             MATOUT12
      IF(IMASTD)52,1,41                                                 MATOUT13
1     INR=NR                                                            MATOUT14
      INC=NC                                                            MATOUT15
2     IF(IMASTD)52,3,45                                                 MATOUT16
3     ICP=NCPR+1                                                        MATOUT17
      IF(INC-NCPR)51,51,4                                               MATOUT18
4     NCPR=NCPR+NCP                                                     MATOUT19
      IF(INC-NCPR)5,6,6                                                 MATOUT20
5     NCPR=INC                                                          MATOUT21
6     LRP=IR-1                                                          MATOUT22
7     IRP=LRP+1                                                         MATOUT23
      IF(LRP-INR)8,2,2                                                  MATOUT24
8     LRP=LRP+50                                                        MATOUT25
      IF(INR-LRP)9,10,10                                                MATOUT26
9     LRP=INR                                                           MATOUT27
10    M3=0                                                              MATOUT28
      NPG=NPG+1
      WRITE(6,100) (HNAME(I),I=1,12)                                    MATOUT30
      WRITE (6,101)                                                     MATOUT31
      CALL FILL(FMAT(1),8H(1H      )
      CALL FILL(FMAT(2),8H,    3X  )
      IF(INMVR.NE.1) CALL FILL(FMAT(2),',12X     ')
      M1=2                                                              MATOUT37
      GO TO (14,14,17),MIT
```

```
14    DO 15 M2=ICP,NCPR                                                  MATOUT38
      M3=M3+1                                                            MATOUT39
      FMAT(M3+2)=FMT(2)
      IF (INMVR.EQ.3) FMAT(M3+2)=FMT(6)
15    D1(M3)=M2+1-IC
16    GO TO (18,17,17),MIT                                               MATOUT42
17    CALL FILL(FMAT(M3+3),8H,3X14HME)
      CALL FILL(FMAT(M3+4),8HANS.STD.)                                   MATOUT44
      CALL FILL(FMAT(M3+5),8HDEV.)    )                                  MATOUT45
      CALL FILL(FMAT(M3+6),8H         )                                  MATOUT46
      GO TO (18,19,21),MIT                                               MATOUT47
18    CALL FILL(FMAT(M3+3),8H)        )                                  MATOUT48
19    IF (INMVR.NE.3) WRITE (6,FMAT) (D1(M2),M2=1,M3)
      IF (INMVR.EQ.3) WRITE (6,FMAT) (VARNAM(J),J=ICP,NCPR)
      DO 20 M2=ICP,NCPR                                                  MATOUT50
      M1=M1+1                                                            MATOUT51
20    FMAT(M1)=FMT(3)                                                    MATOUT52
      GO TO (24,22),MIT                                                  MATOUT53
21    WRITE (6,FMAT)                                                     MATOUT54
22    FMAT(M1+1)=FMT(4)                                                  MATOUT55
      FMAT(M1+2)=FMT(5)                                                  MATOUT56
      CALL FILL(FMAT(M1+3),8H)        )                                  MATOUT57
24    WRITE (6,101)                                                      MATOUT58
      FMAT(2)=D(1)
      IF (INMVR.GE.2) FMAT(2)=D(2)
      M3=2                                                               MATOUT60
      DO 40 M1=IRP,LRP                                                   MATOUT61
      M4=0                                                               MATOUT62
      GO TO (25,25,36),MIT                                               MATOUT63
25    GO TO (31,28,26),ISOUT                                             MATOUT64
26    IF(M1-ICP)31,30,27                                                 MATOUT65
27    IF(M1-NCPR)272,271,273                                             MATOUT66
271   FMAT(M3)=FMT(3)                                                    MATOUT67
      GO TO 30                                                           MATOUT68
272   IF(M3-2)275,275,271                                                MATOUT69
273   IF(M3-2)31,31,274                                                  MATOUT70
274   FMAT(M3)=FMT(3)                                                    MATOUT71
      GO TO 31                                                           MATOUT72
275   M3=M1-ICP+2                                                        MATOUT73
      GO TO 30                                                           MATOUT74
28    IF(M1-NCPR)29,29,2                                                 MATOUT75
29    IF(M1-ICP)31,31,30                                                 MATOUT76
30    M3=M3+1                                                            MATOUT77
      FMAT(M3)=FMT(1)                                                    MATOUT78
31    DO 35 M2=ICP,NCPR                                                  MATOUT79
      GO TO (34,33,32),ISOUT                                             MATOUT80
32    IF(M1-M2)34,35,34                                                  MATOUT81
33    IF(M1-M2)34,34,35                                                  MATOUT82
34    M4=M4+1                                                            MATOUT83
      M5=(M2-1)*NRD+M1                                                   MATOUT84
      D1(M4)=A(M5)*B1                                                    MATOUT85
35    CONTINUE                                                           MATOUT86
      GO TO (37,36),MIT                                                  MATOUT87
36    M5=(M1-1)*NRD+MASTD                                                MATOUT88
      D1(M4+1)=A(M5)                                                     MATOUT89
      M5=(MASTD-1)*NRD+M1                                                MATOUT90
      M4=M4+2                                                            MATOUT91
      D1(M4)=A(M5)                                                       MATOUT92
37    L1=M1+1-IR
      GO TO (38,39,39),INMVR
38    WRITE (6,FMAT) L1,(D1(M2),M2=1,M4)
      GO TO 40                                                           MATOUT95
39    WRITE (6,FMAT) VARNAM(M1),L1,(D1(M2),M2=1,M4)
40    CONTINUE                                                           MATOUT97
      GO TO 7                                                            MATOUT98
41    GO TO (42,43,43),INMVR
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   42   ISP=116/NCP                                                          MATOUT 0
        GO TO 44                                                             MATOUT 1
   43   ISP=110/NCP                                                          MATOUT 2
   44   INR=NR                                                               MATOUT 3
        INC=NC                                                               MATOUT 4
   45   ICP=NCPR+1                                                           MATOUT 5
        IF(INC-NCPR)49,49,46                                                 MATOUT 6
   46   NCPR=NCPR+NCP                                                        MATOUT 7
        IF(INC-NCPR)47,6,6                                                   MATOUT 8
   47   MSP=(NCPR-INC)*ISP                                                   MATOUT 9
        NCPR=INC                                                             MATOUT10
        IF(MSP-2*IMASTD)6,48,48                                              MATOUT11
   48   MIT=2                                                                MATOUT12
        GO TO 6                                                              MATOUT13
   49   GO TO (50,51,51),MIT                                                 MATOUT14
   50   MIT=3                                                                MATOUT15
        GO TO 6                                                              MATOUT16
   51   RETURN                                                               MATOUT17
   52   WRITE (6,102)                                                        MATOUT18
  100 FORMAT(1HO,2X,12A8)
  101 FORMAT(1H ,2X)                                                        MATOUT20
  102 FORMAT(1H ,46HLENGTH OF MEAN AND STD. DEV. FIELD IS NEGATIVE)         MATOUT21
        RETURN                                                              MATOUT22
        END
        SUBROUTINE FILL(X,Y)
        REAL*8 X,Y
        X=Y
        RETURN
        END
        SUBROUTINE XIHAT(X,S,X2,S2,M,B,M2,B2,N ,N2,NOBS,NOBS2,NSAMP,XIHAT)
C
C       THIS SUBROUTINE (1) OPTIONALLY COMPUTES ESTIMATES OF MEANS AND
C       COVARIANCES FROM SAMPLE MEANS AND COVARIANCES FOR ONE OR TWO
C       SAMPLES.  (2) COMPUTES THE VALUES OF XIHAT(I), I=1,2,...,N, THE
C       TEST STATISTICS FORM ESTIMATED AND SAMPLE MEANS AND COVARIANCES
C       FOR ONE OR TWO SAMPLES.
C
C       X       SAMPLE MEANS FOR FIRST SAMPLE
C       S       SAMPLE VAR/COV MATRIX FOR FIRST SAMPLE
C       X2       SAMPLE MEANS FOR SECOND SAMPLE
C       S2       SAMPLE VAR/COV MATRIX FOR SECOND SAMPLE
C       M       ESTIMATED MEANS FOR FIRST SAMPLE
C       B       ESTIMATED VAR/COV MATRIX FOR FIRST SAMPLE
C       M2       ESTIMATED MEANS FOR SECOND SAMPLE
C       B2       ESTIMATED VAR/COV MATRIX FOR SECOND SAMPLE
C       N       NUMBER OF VARIABLES IN FIRST SAMPLE
C       N2       NUMBER OF VARIABLES IN SECOND SAMPLE
C       NOBS      NUMBER OF OBSERVATIONS FOR FIRST SAMPLE
C       NOBS2      NUMBER OF OBSERVATIONS FOR SECOND SAMPLE
C       NSAMP = 1 IF ONLY ONE SAMPLE
C               2 IF THERE ARE TWO SAMPLES
C       XIHAT      VECTOR OF HYPOTHESES
C
C**********  NOTE:  IN REFERENCES TO S, S2, B, B2,  THE SECOND
C             SUBSCRIPT MUST ALWAYS BE GREATER THAN OR EQUAL TO THE FIRST.
C
        IMPLICIT REAL*8(A-H,O-Z)
        REAL*8 M(10),M2(10),B(10,10),B2(10,10)
        DIMENSION X(10),X2(10),S(10,10),S2(10,10)
        DIMENSION XIHAT(1)
        DO 9998 I=1,N
        M(I)=X(I)
        DO 9998 J=I,N
        B(I,J)=S(I,J)
 9998 CONTINUE
        IF(NSAMP.EQ.1) GO TO 100
```

```
      DO 9999 I=1,42
      M2(I)=X2(I)
      DO 9999 J=I,42
      S2(I,J)=S2(I,J)
 9999 CONTINUE
C
C
C     IF THE USER WISHES TO SPECIFY ESTIMATES OTHER THAN SAMPLE MEANS
C     AND COVARIANCES, HE MUST INSERT THE CODE BETWEEN THE FOLLOWING
C     ASTERISK CARDS.  ESTIMATES NOT SPECIFIED BY USER CODE WILL BE
C     ASSUMED TO BE SAMPLE MEANS AND COVARIANCES.
C     THE FOLLOWING RULES MUST BE FOLLOWED:
C          (1) THE ESTIMATES SUPPLIED MUST APPEAR TO THE LEFT OF AN
C              EQUALS SIGN.
C          (2) STATEMENT NUMBERS 9998 AND 9999 MUST NOT BE USED.
C          (3) THE FIRST LINE OF CODE MUST NOT BE A FORMAT STATEMENT
C              AND MUST HAVE THE STATEMENT NUMBER 100.
C
C*************************************************************************
  100 S(1,1)=.500*(S(1,1)+S(2,2))
      S(2,2)=S(1,1)
      S(3,3)=.500*(S(3,3)+S(4,4))
      S(4,4)=S(3,3)
      S(1,3)=.2500*(S(1,3)+S(1,4)+S(2,3)+S(2,4))
      S(1,4)=S(1,3)
      S(2,3)=S(1,3)
      S(2,4)=S(1,3)
C*************************************************************************
C
C
C     THE USER MUST INSERT CODE BETWEEN THE FOLLOWING ASTERISK CARDS
C     WHICH COMPUTES XIHAT(I), I=1,2,...,NH.  THE FOLLOWING RULES MUST BE
C     FOLLOWED.
C          (1) XIHAT(I) FOR I=1,2,...,NH MUST APPEAR TO THE LEFT OF
C              AN EQUALS SIGN.
C          (2) STATEMENT NUMBERS 9998 AND 9999 MUST NOT BE USED.
C          (3) STATEMENT NUMBERS USED IN SPECIFYING ESTIMATES (IF ANY)
C              MUST NOT BE REPEATED.
C          (4) IF NO ESTIMATES WERE SPECIFIED ABOVE, THE FIRST LINE
C              OF CODE MUST NOT BE A FORMAT STATEMENT AND MUST HAVE THE
C              STATEMENT NUMBER 100.
C
C
C*************************************************************************
      XIHAT(1)=S(1,3)*S(1,3)-S(1,2)*S(3,4)
C*************************************************************************
C
C
      RETURN
      END
```

PROGRAM TO TEST HYPOTHESES ABOUT MEANS AND COVARIANCES FOR LARGE SAMPLES.

NUMBER OF SAMPLES = 1 12:17:18 3/06/73

NUMBER OF HYPOTHESES = 1

DATA: TEST DATA 19 HO: RHO13/SQRT(RHO11*RHO33) = 1

NUMBER OF OBSERVATIONS = 649
NUMBER OF VARIABLES = 4
INPUT = 1

SAMPLE MEANS

1	2	3	4
0.0	0.0	0.0	0.0

SAMPLE VARIANCE/COVARIANCE MATRIX

	1.	2.	3.	4.
1	0.86398E 02	0.57775E 02	0.56855E 02	0.58399E 02
2		0.86264E 02	0.59312E 02	0.59668E 02
3			0.97285E 02	0.73820E 02
4				0.97819E 02

ESTIMATED MEANS AND VAR/COV FOR FIRST SAMPLE

ESTIMATED MEANS

1	2	3	4
0.0	0.0	0.0	0.0

ESTIMATED VARIANCE/COVARIANCE MATRIX

	1.	2.	3.	4.
1	0.96331E 02	0.57775E 02	0.58686E 02	0.58686E 02
2		0.96331E 02	0.58686E 02	0.58686E 02
3			0.97552E 02	0.73820E 02
4				0.97552E 02

NUMERICAL VALUES OF NULL HYPOTHESES

(1) -0.82942587D 03 (

DERIVATIVES OF XIHAT(1) FOR FIRST SAMPLE

MEANS

0.0	0.0	0.0	0.0

VARIANCE/COVARIANCE MATRIX

	1.	2.	3.	4.
1	0.0	-0.73823E 02	0.29343E 02	0.29343E 02
2		0.0	0.29343E 02	0.29343E 02
3			0.0	-0.57775E 02
4				0.0

VARIANCE/COVARIANCE MATRIX OF XIHATS

	1.

1 0.26275E 05

INVERSE OF VARIANCE MATRIX OF XHATS

1.

1 0.33030E-04

CHI-SQUARE = 0.25629454D 02 D.F. = 1. CHISQR/DF = 0.25629454D 02 PROBABILITY = 0.000000

Reference

Lord, F. M. Automated hypothesis tests and standard errors for non-standard problems (with description of computer package by Martha Stocking). Research Bulletin 72-42 (rev. ed.). Princeton, N.J.: Educational Testing Service, 1973.